

Performance Analysis of BTPS (NTPC) Thermal Power Plant

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Abstract: Current scenario depicts that the rate at which the demand for power is increasing, is significantly higher than the rate at which it is being generated. The increasing demand for power has made the area of power plants of prime concern. Boiler is the lifeline of a thermal power plant, as the chemical energy of fuel (content in coal) is converted into heat energy in a boiler, so the efficiency of boiler directly affects the overall efficiency of the plant. Gradually with the passage of time, performance of boilers deteriorate due to several factors like fouling, poor operation, maintenance etc. So it becomes necessary to calculate the boiler's performance from time to time, to improve the overall plant performance. This paper is concerned with calculating the efficiency of boiler as one of the most prominent types of performance measurement in any steam power plant. The heat rate of a conventional coal fired power plant is a measure of how efficiently the plant is able to convert the chemical energy contained in the fuel into electrical energy. Heat rate is expressed in terms of Kcal/KWh. The objective of monitoring the performance of a boiler is to control the heat rate of the plant. This paper deals with the calculation of operating efficiency of Boiler and its major losses to evaluate the overall performance of Badarpur Thermal Power Station (NTPC) Badarpur 210 MW unit in India.

keywords: Thermal Power Station, Indirect Method.

I. INTRODUCTION

The purpose of the study outlined in this is to identify the important performance parameters for a coal fired power station, various losses in thermal power station and its calculation methodology.

Most of the power plants are planned and designed by the energetic performance criteria, based not only on the first law of thermodynamics, but the real useful energy loss cannot be justified by the first law of thermodynamics, because it does not differentiate between the quality and quantity of energy. However, industrial plants are not always aware of energy-efficiency improvement potentials.

Conducting an energy audit is one of the first steps in identifying these potentials. Even so, many plants do not have the capacity to conduct an effective energy audit. In some countries, government policies and programs aim to assist industry to improve competitiveness through increased energy efficiency.

However, usually only limited technical and financial resources for improving energy efficiency are available, especially for small and medium-sized enterprises. Information on energy auditing and practices should, therefore, be prepared and disseminated to industrial plants.

Energy audits assist industrial companies or facilities in understanding how they use energy and help to identify the areas where waste occurs and where opportunities for improvement exist. Energy efficiency benchmarking and comparisons can be

used to assess a company's performance relative to that of its competitors or its own performance in the past. Benchmarking can also be used for assessing the energy performance improvement achieved by the implementation of energy-efficiency measures.

Also, on a national level, policy makers can use benchmarking to prioritize energy-saving options and to design policies to reduce greenhouse gas emissions.

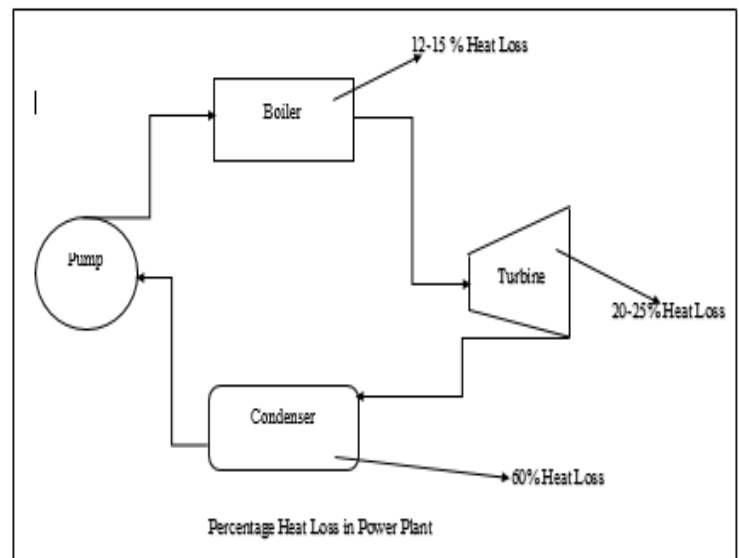


Fig. 1: Schematic diagram of Overall plant Losses

II. RELATED WORK

NTPC Limited is the largest thermal power generating company of India. A public sector company, it was incorporated in the year 1975 to accelerate power development in the country as a wholly owned company of the Government of India. At present, Government of India holds 89.5% of the total equity shares of the company.

NTPC has actively gone for adoption of best international practices on environment, occupational health and safety areas. The organization has pursued the Environmental Management System (EMS) ISO 14001 and the Occupational Health and Safety Assessment System OHSAS 18001 at its different establishments. As a result of pursuing these practices, all NTPC power stations have been certified for ISO 14001 & OHSAS 18001 by reputed national and international Certifying Agencies.

Purpose of the Performance Test

- . To find out the efficiency of the boiler
- . To find out the Evaporation ratio

The purpose of the performance test is to determine actual performance and efficiency of the boiler and compare it with

design values or norms. It is an indicator for tracking day-to-day and season-to-season variations in boiler efficiency and energy efficiency improvements.

FORMULA FOR BOILER EFFICIENCY CALCULATION

$$1. \text{ Boiler Efficiency, } \eta = \frac{\text{Heat output}}{\text{Heat Input}} \times 100$$

$$= \frac{\text{Heat in steam output (kCals)}}{\text{Heat in Fuel Input (kCals)}} \times 100$$

$$2. \text{ Evaporation Ratio} = \frac{\text{Quantity of Steam Generation}}{\text{Quantity of fuel Consumption}}$$

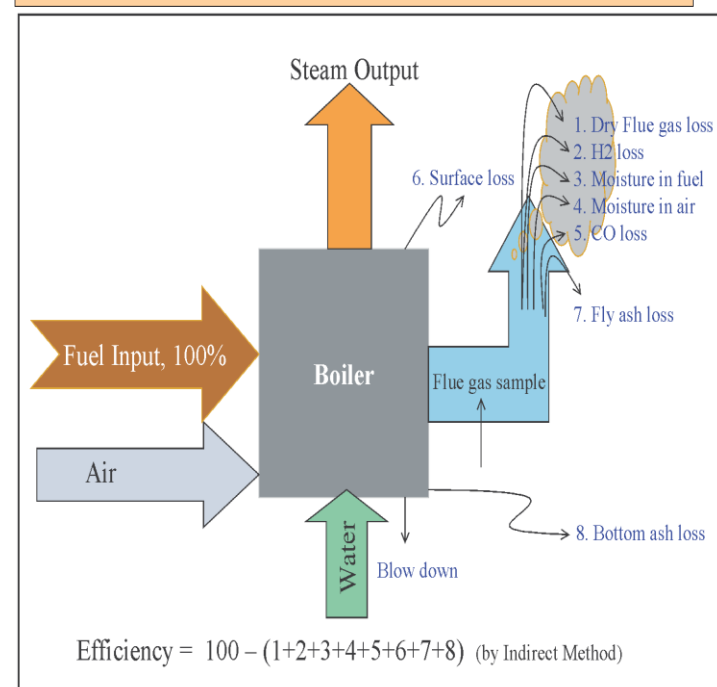


Fig. 2: Schematic diagram of Boiler Losses(Ref. BEE)

The following losses are applicable to liquid, gas and solid fired boiler

- L1. Loss due to dry flue gas (sensible heat)
- L2. Loss due to hydrogen in fuel (H₂)
- L3. Loss due to moisture in fuel (H₂O)
- L4. Loss due to moisture in air (H₂O)
- L5. Loss due to carbon monoxide (CO)
- L6. Loss due to surface radiation, convection and other unaccounted*.

*Losses which are insignificant and are difficult to measure.

The following losses are applicable to solid fuel fired boiler in addition to above

- L7. Unburnt losses in fly ash (Carbon)
 - L8. Unburnt losses in bottom ash (Carbon)
- Boiler Efficiency by indirect method = 100 - (L1 + L2 + L3 + L4 + L5 + L6 + L7 + L8)

Boiler Efficiency by Indirect Method: Calculation Procedure and Formula

In order to calculate the boiler efficiency by indirect method, all the losses that occur in the boiler must be established. These losses are conveniently related to the amount of fuel burnt. In this way it is easy to compare the performance of various boilers with different ratings.

The various losses associated with the operation of a boiler are discussed below with required formula.

However it is suggested to get a ultimate analysis of the fuel fired periodically from a reputed laboratory.

Theoretical (stoichiometric) air fuel ratio and excess air supplied are to be determined first for computing the boiler losses. The formula is given below for the same.

a) Theoretical air required for combustion	= $\frac{[(11.6 \times C) + \{34.8 \times (H_2 - O_2/8)\} + (4.35 \times S)]}{100}$ kg/kg of fuel. [from fuel analysis]
	Where C, H ₂ , O ₂ and S are the percentage of carbon, hydrogen, oxygen and sulphur present in the fuel.
b) % Excess Air supplied (EA)	= $\frac{O_2\%}{21 - O_2\%} \times 100$ [from flue gas analysis]
	Normally O ₂ measurement is recommended. If O ₂ measurement is not available, use CO ₂ measurement
	= $\frac{7900 \times [(CO_2\%)_t - (CO_2\%)_a]}{(CO_2\%)_a \times [100 - (CO_2\%)_t]}$ [from flue gas analysis]
Where, (CO ₂ %) _t	= Theoretical CO ₂
(CO ₂ %) _a	= Actual CO ₂ % measured in flue gas
(CO ₂) _t	= $\frac{\text{Moles of C}}{\text{Moles of N}_2 + \text{Moles of C}}$
Moles of N ₂	= $\frac{\text{Wt of N}_2 \text{ in theoretical air}}{\text{Mol. wt of N}_2} + \frac{\text{Wt of N}_2 \text{ in fuel}}{\text{Mol. Wt of N}_2}$
Moles of C	= $\frac{\text{Wt of C in fuel}}{\text{Molecular Wt of C}}$
c) Actual mass of air supplied/ kg of fuel (AAS)	= $\{1 + EA/100\} \times \text{theoretical air}$

The following are the data collected for a boiler using coal as the fuel. Find out the boiler efficiency by indirect method.

Fuel firing rate = 5599.17 kg/hr
 Steam generation rate = 21937.5 kg/hr
 Steam pressure = 43 kg/cm² (g)
 Steam temperature = 377 °C
 Feed water temperature = 96 °C
 %CO₂ in Flue gas = 14
 %CO in flue gas = 0.55
 Average flue gas temperature = 190 °C
 Ambient temperature = 31 °C
 Humidity in ambient air = 0.0204 kg / kg dry air

Surface temperature of boiler = 70 °C
Wind velocity around the boiler = 3.5 m/s
Total surface area of boiler = 90 m²
GCV of Bottom ash = 800 kCal/kg
GCV of fly ash = 452.5 kCal/kg
Ratio of bottom ash to fly ash = 90:10

Fuel Analysis (in %)

Ash content in fuel = 8.63
Moisture in coal = 31.6
Carbon content = 41.65
Hydrogen content = 2.0413
Nitrogen content = 1.6
Oxygen content = 14.48
GCV of Coal = 3501 kCal/kg

Boiler efficiency by indirect method

Step. 1 Find theoretical air requirement

Theoretical air required for complete combustion
= [(11.6 x C) + {34.8 x (H₂ - O₂/8)} + (4.35 x S)] / 100 kg/kg of coal
= [(11.6 x 41.65) + {34.8 x (2.0413 - 14.48/8)} + (4.35 x 0)] / 100
= 4.91 kg / kg of coal

Step 2. Find the theoretical CO₂%

$$\begin{aligned} \% \text{CO}_2 \text{ at theoretical condition (CO}_2\%) &= \frac{\text{Moles of C}}{\text{Mol. Wt of N}_2} \times \frac{\text{Wt. of N}_2 \text{ in theoretical air}}{\text{Wt. of N}_2 \text{ in fuel}} \\ &= \frac{4.91 \times 77/100}{28} + \frac{0.016}{28} = 0.1356 \end{aligned}$$

Step. 3 To find Excess air supplied

$$\begin{aligned} \text{Actual CO}_2 \text{ measured in flue gas} &= 14.0\% \\ \% \text{ Excess air supplied (EA)} &= \frac{7900 \times [(\text{CO}_2\%)_t - (\text{CO}_2\%)_a]}{(\text{CO}_2\%)_a \times [100 - (\text{CO}_2\%)_t]} \\ &= \frac{7900 \times [20.37 - 14]}{14 \times [100 - 20.37]} \\ &= 45.17\% \end{aligned}$$

Step. 4 To find actual mass of air supplied

$$\begin{aligned} \text{Actual mass of air supplied} &= \{1 + \text{EA}/100\} \times \text{theoretical air} \\ &= \{1 + 45.17/100\} \times 4.91 \\ &= 7.13 \text{ kg/kg of coal} \end{aligned}$$

Step. 5 to find actual mass of dry flue gas

$$\begin{aligned} \text{Mass of dry flue gas} &= \text{Mass of CO}_2 + \text{Mass of N}_2 \text{ content in the fuel} + \text{Mass of N}_2 \text{ in the combustion air supplied} + \text{Mass of oxygen in flue gas} \\ &= \frac{0.4165 \times 44}{12} + 0.016 + \frac{7.13 \times 77}{100} + \frac{(7.13 \times 4.91) \times 23}{100} \\ &= 7.54 \text{ kg / kg of coal} \end{aligned}$$

Step. 6 To find all losses

$$\begin{aligned} \% \text{ Heat loss in dry flue gas} &= \frac{m \times C_p \times (T_f - T_a)}{\text{GCV of Fuel}} \times 100 \\ &= \frac{7.54 \times 0.23 \times (190 - 31)}{3501} \times 100 \\ &= 1.78\% \end{aligned}$$

$$\begin{aligned} 2. \% \text{ Heat loss due to formation} &= \frac{9 \times \text{H}_2 \times \{584 + C_p (T_f - T_a)\}}{\text{GCV of fuel}} \times 100 \\ &= \frac{9 \times 0.02041 \times \{584 + 0.45(190 - 31)\}}{3501} \times 100 \\ &= 3.4\% \end{aligned}$$

$$\begin{aligned} 3. \% \text{ Heat loss due to moisture in} &= \frac{M \times \{584 + C_p (T_f - T_a)\}}{\text{GCV of Fuel}} \times 100 \\ &= \frac{0.316 \times \{584 + 0.45(190 - 31)\}}{3501} \times 100 \\ &= 5.91\% \end{aligned}$$

$$\begin{aligned} 4. \% \text{ Heat loss due to moisture} &= \frac{\text{AAS} \times \text{humidity} \times C_p \times (T_f - T_a) \times 100}{\text{GCV of Fuel}} \\ &= \frac{7.13 \times 0.0204 \times 0.45 \times (190 - 31) \times 100}{3501} \\ &= 0.29\% \end{aligned}$$

$$\begin{aligned} 5. \% \text{ Heat loss due to partial conversion of C to CO (L}_5\text{)} &= \frac{\% \text{CO} \times C}{\% \text{CO} + (\% \text{CO}_2)_a} + \frac{5744}{\text{GCV of fuel}} \times 100 \\ &= \frac{0.55 \times 0.4165}{0.55 + 14} + \frac{5744}{3501} \times 100 \\ &= 2.58\% \end{aligned}$$

$$\begin{aligned} 6. \text{ Heat loss due to radiation} &= 0.548 \times [(343/55.55)^4 - (304/55.55)^4] + 1.957 \times (343 \times 304)^{1.25} \times \text{sq. rt of } [(196.85 \times 3.5 + 68.9) / 68.9] \\ &= 633.3 \text{ w/m}^2 \\ &= 633.3 \times 0.86 \\ &= 544.64 \text{ kCal / m}^2 \end{aligned}$$

Total radiation and convection = 544.64 x 90
loss per hour = 49017.6 kCal

$$\begin{aligned} \% \text{ radiation and convection loss} &= \frac{49017.6 \times 100}{3501 \times 5599.17} \\ &= 0.25\% \end{aligned}$$

7. % Heat loss due to unburnt in fly ash

$$\begin{aligned} \% \text{ Ash in coal} &= 8.63 \\ \text{Ratio of bottom ash to fly ash} &= 90:10 \\ \text{GCV of fly ash} &= 452.5 \text{ kCal/kg} \\ \text{Amount of fly ash in 1 kg of coal} &= 0.1 \times 0.0863 = 0.00863 \text{ kg} \\ \text{Heat loss in fly ash} &= 0.00863 \times 452.5 = 3.905 \text{ kCal / kg of coal} \\ \% \text{ heat loss in fly ash} &= 3.905 \times 100 / 3501 \\ &= 1.11\% \end{aligned}$$

8. % Heat loss due to unburnt in bottom ash

$$\begin{aligned} \text{GCV of bottom ash} &= 800 \text{ kCal/kg} \\ \text{Amount of bottom ash in 1 kg of} &= 0.9 \times 0.0863 \text{ coal} = 0.077 \text{ kg} \\ \text{Heat loss in bottom ash} &= 0.077 \times 800 = 62.136 \text{ kCal/kg of coal} \\ \% \text{ Heat loss in bottom ash} &= 62.136 \times 100 / 3501 \\ &= 1.77\% \end{aligned}$$

Boiler efficiency by indirect method = $100 - (L1 + L2 + L3 + L4 + L5 + L6 + L7 + L8)$

$$= 100 - (7.88 + 3.44 + 5.91 + 0.29 + 2.58 + 0.25 + 0.11 + 1.77)$$

$$= 100 - 22.23$$

$$= 77.77 \%$$

1.8.2 Efficiency for an oil fired boiler

The following are the data collected for a boiler using furnace oil as the fuel. Find out the boiler efficiency by indirect method.

Input/Output Parameter kCal / kg of % loss coal

Heat Input = 3501 100

Losses in boiler

1. Dry flue gas, L1 = 275.88 7.88

2. Loss due to hydrogen in fuel, L2 = 120.43 3.44

3. Loss due to moisture in fuel, L3 = 206.91 5.91

4. Loss due to moisture in air, L4 = 10.15 0.29

5. Partial combustion of C to CO, L5 = 90.32 2.58

6. Surface heat losses, L6 = 8.75 0.25

7. Loss due to Unburnt in fly ash, L7 = 3.85 0.11

8. Loss due to Unburnt in bottom ash, L8 = 61.97 1.77

Boiler Efficiency = $100 - (L1 + L2 + L3 + L4 + L5 + L6 + L7 + L8) = 77.77 \%$

Ultimate analysis (%)

Carbon = 84

Hydrogen = 12

Nitrogen = 0.5

Oxygen = 1.5

Sulphur = 1.5

Moisture = 0.5

GCV of fuel = 10000 kCal/kg

Fuel firing rate = 2648.125 kg/hr

Surface Temperature of boiler = 80 °C

Surface area of boiler = 90 m²

Humidity = 0.025 kg/kg of dry air

Wind speed = 3.8 m/s

Flue gas analysis (%)

Flue gas temperature = 190°C

Ambient temperature = 30°C

CO₂ in flue gas by volume = 10.8

O₂ in flue gas by volume = 7.4

$$\begin{aligned} \text{a) Theoretical air required} &= [(11.6 \times C) + \{[34.8 \times (H_2 - O_2/8)] \\ &+ (4.35 \times S)] / 100 \text{ kg/kg of fuel. [From fuel analysis]} \\ &= [(11.6 \times 84) + \{[34.8 \times (12 - 1.5/8)] + (4.35 \times 1.5)\}] / 100 \\ &= 13.92 \text{ kg/kg of oil} \end{aligned}$$

$$\begin{aligned} \text{b) Excess Air supplied (EA)} &= (O_2 \times 100) / (21 - O_2) \\ &= (7.4 \times 100) / (21 - 7.4) \\ &= 54.4 \% \end{aligned}$$

$$\text{c) Actual mass of air supplied/ kg of fuel} = \{1 + EA/100\} \times \text{theoretical air}$$

$$= \{1 + 54.4/100\} \times 13.92$$

$$= 21.49 \text{ kg / kg of fuel}$$

Mass of dry flue gas = Mass of (CO₂ + SO₂ + N₂ + O₂) in flue gas + N₂ in air we are supplying

$$= \frac{0.84 \times 44}{12} + \frac{0.015 \times 64}{32} + 0.005 + \frac{7.4 \times 23}{100} + \frac{21.49 \times 77}{100}$$

$$= 21.36 \text{ kg / kg of oil}$$

$$\% \text{ Heat loss in dry flue gas} = \frac{m \times C_p \times (T_f - T_a)}{\text{GCV of fuel}} \times 100$$

$$= \frac{21.36 \times 0.23 \times (190 - 30)}{10000} \times 100$$

$$L1 = 7.86 \%$$

$$\% \text{ Heat loss due to evaporation of water due to H}_2 \text{ in fuel (\%)} = \frac{9 \times H_2 \times \{584 + C_p (T_f - T_a)\}}{\text{GCV of fuel}} \times 100$$

$$= \frac{9 \times 0.12 \times \{584 + 0.45 (190 - 30)\}}{10000} \times 100$$

$$L2 = 7.08 \%$$

$$\% \text{ Heat loss due to moisture in fuel} = \frac{M \times \{584 + C_p (T_f - T_a)\}}{\text{GCV of fuel}} \times 100$$

$$= \frac{0.005 \times \{584 + 0.45 (190 - 30)\}}{10000} \times 100$$

$$L3 = 0.033 \%$$

$$\% \text{ Heat loss due to moisture in air} = \frac{AAS \times \text{humidity} \times C_p \times (T_f - T_a)}{\text{GCV of fuel}} \times 100$$

$$L4 = 0.38 \%$$

$$\text{Radiation and convection loss} = 0.548 \times [(T_s / 55.55)^4 - (T_a / 55.55)^4] + 1.957 \times (T_s - T_a)^{1.25} \times \text{sq.rt of } [(196.85 V_m + 68.9) / 68.9]$$

$$= 0.548 \times [(353 / 55.55)^4 - (303 / 55.55)^4] + 1.957 \times (353 - 303)^{1.25} \times \text{sq.rt of } [(196.85 \times 3.8 + 68.9) / 68.9]$$

$$= 1303 \text{ W/m}^2$$

$$= 1303 \times 0.86$$

$$= 1120.58 \text{ kCal / m}^2$$

$$\begin{aligned} \text{Total radiation and convection loss per hour} &= 1120.58 \times 90 \text{ m}^2 \\ &= 100852.2 \text{ kCal} \end{aligned}$$

$$\% \text{ Radiation and convection loss} = \frac{100852.2 \times 100}{10000 \times 2648.125}$$

$$L6 = 0.38 \%$$

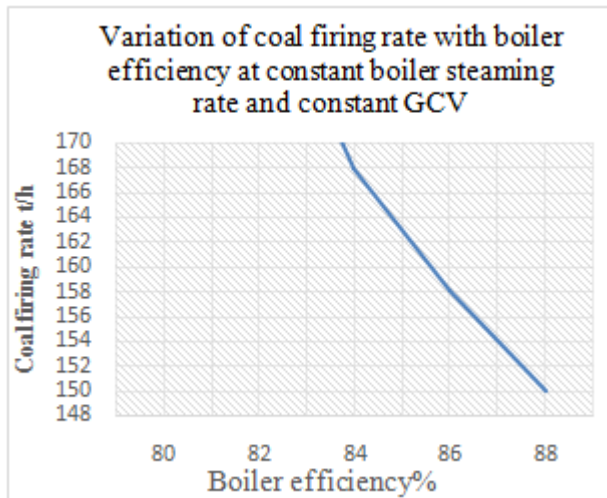
Normally it is assumed as 0.5 to 1 % for simplicity

$$\text{Boiler efficiency by indirect method} = 100 - (L1 + L2 + L3 + L4 + L6)$$

$$= 100 - (7.86 + 7.08 + 0.033 + 0.38 + 0.38)$$

$$= 100 - 15.73$$

$$= 84.27 \%$$



Summary of Heat Balance for the Boiler Using Furnace Oil

Input/output Parameter kCal / kg of %Loss Furnace oil
Heat Input = 10000 100

Losses in boiler:

1. Dry flue gas, $L_1 = 786.786$
2. Loss due to hydrogen in fuel, $L_2 = 708.708$
3. Loss due to Moisture in fuel, $L_3 = 3.30.033$
4. Loss due to Moisture in air, $L_4 = 38.0.38$
5. Partial combustion of C to CO, $L_5 = 0.0$
6. Surface heat losses, $L_6 = 38.0.38$

Boiler Efficiency = $100 - (L_1 + L_2 + L_3 + L_4 + L_6) = 84.27\%$

1.9 Factors Affecting Boiler Performance

The various factors affecting the boiler performance are listed below:

- . Periodical cleaning of boilers
- . Periodical soot blowing
- . Proper water treatment programme and blow down control
- . Draft control
- . Excess air control
- . Percentage loading of boiler
- . Steam generation pressure and temperature
- . Boiler insulation
- . Quality of fuel

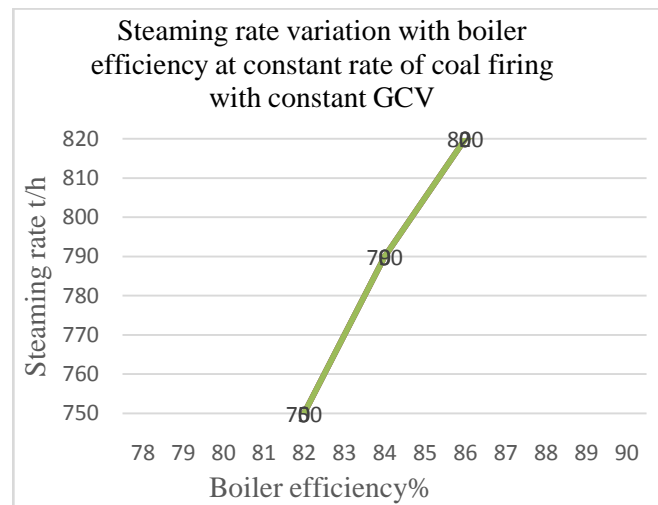
All these factors individually/combined, contribute to the performance of the boiler and reflected either in boiler efficiency or evaporation ratio. Based on the results obtained from the testing further improvements have to be carried out for maximizing the performance. The test can be repeated after modification or rectification of the problems and compared with standard norms. Energy auditor should carry out this test as a routine manner once in six months and report to the management for necessary action.

EXPERIMENTAL RESULTS (AT LAST)

CONCLUSION AND RECOMMENDATIONS

The measured temperature and pressure of the steam cannot be used directly and associated values of the other properties such as enthalpy and entropy are required to be taken either from steam tables or from Mollier Chart.

Next sections are devoted on mathematical model to evaluate all the energy efficiency and exergy parameters by straight way using the measurable parameters



The overall conclusion of the present paper are as follows:

1. It was found that increase in the feed water temperature by six degree centigrade boiler efficiency increases by one percent.
2. Decrease in temperature of flue gas by twenty degree centigrade improves the efficiency by one percent.
3. Indirect method of boiler efficiency calculation is more accurate as compared to the direct method as in this errors in measurement do not make significant change in efficiency.
4. The direct method of calculation gives the marginal value of efficiency so it is difficult to find correct efficiency of boiler and identify the losses.
5. For improvement of radiation losses, high quality insulation coupled with water cooled furnaces keep the value low.
6. For high efficiency of boiler it is determined that improvement in the Gross Calorific Value (GCV) of coal improves the heat rate of thermal power plant.
7. Excess air directly affects the class of combustion. It was found that maintaining excess air with 3-4% of excess oxygen increases the boiler efficiency.

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Experimental results

S.NO.	DESCRIPTION OF PLANT PARAMETER AND ITS NAME	DATA DESIGNATION	FINAL VALUES AND RESULTS
1.	Dry Flue Gas Loss in %	CinAsh Kg/Kg Coal	0.004836
	$DFL = W * C_{pg} * (T - t)$	Moisture %	11
	$W = \frac{(C/100 + S/267 - CinAsh) * 100 / 12 (CO_2 + CO)}{KgMol/Kg C}$	Ash %	34.5
	= 4.2	VM %	20
		FC %	34.9
2.	Carbon in ash loss in %	Carbon %	37
	CinA * 33820	Hydrogen %	2.8
	= 1.08687	Nitrogen %	0.9
		Sulphur %	0.5
3.	Wet flue gas loss in %	Oxygen %	7.7
	$WFGL = (Mc + 9H) * [C_{ps} * (T - T_s) + LH + S_w * (T_s - t)] / 100 \text{ KJ/Kg C}$	MM % (10% of Ash)	4.1
	$WFGL = [1.88 * (T - 25) + 2442 + 4.2 * (25 - t)] * (Mc + 9H) / 100 \text{ KJ/Kg C}$	GCV (Kcal/Kg)	4109
	= 5.8	GCV (KJ/Kg)	17175.62
4.	Unburnt gas loss in %	DBT deg. C	35.47
	$UGL = 23,717 * (C/100 + S/267 - CinAsh) * CO / 12 (CO_2 + CO) \text{ KJ/kg C}$	WBT deg. C	26.24
	= 0.5		
5.	Moisture in combustion air loss in %	Tf deg. C	600
	MainAirL = Ma * H * (T-t)	O2 % (at APH O/L)	3.56
	$Ma = \frac{(C/100 + S/267 - CinAsh) * 3.03N_2 / 12 (CO_2 + CO)}{Kg/Kg C}$	CO2 %	15.4
	= 0.059130961	C in flyash %	0.4
6.	Sensible heat in ash loss in %	C in bottom ash %	4.6
	$SH_{inAshL} = .8A * C_{pfa} * (FGET - t) + .2A * C_{pba} * (Tf - t)$	mill reject in Kg/hr	547.2
	$C_{pfa} = .836 \text{ \& C}_{pba} = 1.17 \text{ KJ / Kg}$	Float of mill reject % CV	28.3
	= 0.5131226	Guaranteed air i/ItempC	34
7.	Radiation and unaccounted loss in %	APH gas inlet temp °C	348
	$\log_{10} B = 0.8167 - 0.4238 \log_{10} Cap$	APH gas outlet temp °C	132
	= 0.72	air inlet test temp °C	34

		corrected FGET C	132
8.	Heat loss in mill reject in %	Total Air (Kg/Kg Coal)	5.909
	HL in MR=Qr*CVr	Hu Kg/Kg Air	0.0082
	= 0.0986354	Capacity (Kg/sec)	180
9.	TOTAL LOSS in %	Cpfa (of flyash)KJ/KgK	0.836
	= 12.68035	Cpba (of bottom ash)	1.16
10.	Boiler Efficiency by Loss/Indirect method in %	Stoichio. Air Kg/KgC	4.908
	= 86.8696	Excess Air (% of SA)	20
11.	Boiler Efficiency by direct method in %	Coal flow (Kg/Hr)	100000
	$H=(Q_{ms}*(H_{ms}-h_{fw})+Q_{rh}*(H_{hrh}-H_{crh}))/Q_c*CV_c$	CV of mill reject KJ/Kg	1022
	= 88.62	mill reject (Kg/Kg C)	0.0034
		Load MW	210
12.	Turbo-alternator efficiency in %	FW temp. deg C	247
	$H=MW/(Q_{ms}*(H_{ms}-h_{fw})+Q_{rh}*(H_{hrh}-H_{crh}))$	MS temp deg C	540
	= 44.4	CRH temp deg C	342
		HRH temp deg C	540
13.	Over all Unit efficiency in %	MS Pr bar	140
	$H=MW/(Q_c*CV_c)$	Drum Pr bar	120
	= 38.0892		
14.	Turbo-alternator Heat rate (THR) in KJ/KWHr	CRH Pr bar	25.5
	$THR=(Q_{ms}*(H_{ms}-h_{fw})+Q_{rh}*(H_{hrh}-H_{crh}))/MW$	HRH Pr bar	23
	= 8193.0104	MS flow (Qms) Kg/Hr	654900
15.	Over all Unit Heat Rate (UHR) in KJ/KWHr	RH flow (Qrh) Kg/Hr	624800
	$UHR=Q_c*CV_c/MW$	Hms KJ/Kg	3422
	= 9450.144	hfw KJ/Kg	1072
16.	Station Heat Rate (incl. APC)	Hhrh KJ/Kg	3544
	$SHR=UHR*100/(100-\%APC)$	Hcrh KJ/Kg	3080
	= 10271.89565	APC in %	10.6